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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Terance William MEAD

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Date: May 25, 2007

Group Art Unit: 2625

Examiner: Stephen M. Brinich

For: SYSTEM FOR REDUCING SCRATCH VISIBILITY

Mail Stop: Post Issue
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

CLAIM TO PRIORITY

Sir:

In accordance with 35 U.S.C. §119, Applicant confirms the request for priority under the International Convention and submits herewith the following document in support of the claim:

Certified United Kingdom Patent Application No. 0031127.4 filed December 20, 2000

Certified United Kingdom Patent Application No. 0107090.3 filed March 21, 2001

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as First Class Mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on May 25, 2007.

Max Moskowitz

Name of applicant, assignee or Registered Representative

Signature

May 25, 2007

Date of Signature

Respectfully submitted,

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Enclosures

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In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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Patents Form 1/77

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21DEC00 E593179-8 D01631
P01/7700 0.00-0031127.4

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1.	Your reference	IML/42631
2.	Patent application number *(The Patent Office will fill in this part)*	20 DEC 2000 **0031127.4**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Cintel International Limited Watton Road Ware Herts SG12 OAE
	Patents ADP number *(if you know it)*	7121940002
	If the applicant is a corporate body, give the country/state of incorporation	United Kingdom
4.	Title of the invention	FILM SCANNER SCRATCH REDUCTION
5.	Full name, address and postcode in the United Kingdom to which all correspondence relating to this form and translation should be sent	Reddie & Grose 16 Theobalds Road LONDON WC1X 8PL
	Patents ADP number *(if you know it)*	91001

		Country	Priority application *(If you know it)*	Date of filing *(day/month/year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

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Continuation sheets of this form	
Description	10 + 10
Claim(s)	
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Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	-
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature Reddie & Grose

Date 20 December 2000

12. Name and daytime telephone number of person to contact in the United Kingdom

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Notes
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FILM SCANNER SCRATCH REDUCTION

This invention relates to the scanning of cinematographic film to produce electrical signals corresponding to the images stored on the film. Telecine or film scanning equipment used to produce such signals from cinematographic film have been known for many years, and are described for example in "TV and Video Engineers Reference Book" Chapter 39 Butterworth and Heinemann ISBN 0-7506-1021-2. The invention relates particularly to the type of telecine or film scanner that uses a scanning light source such as the applicant's Ursa or C-Reality telecines.

The relevant part of the applicant's C-Reality telecine is described in simple terms with reference to figure 1, which shows in schematic form the detail of this process, however it should be noted that the design detail has been simplified for ease of description. Cathode ray tube (1) produces a raster scan that is imaged onto the film (3) by an imaging lens group (2). The light passing through the film is modulated by the colour and density of the film at each location or pixel scanned, this light being subsequently analysed into it's red, green, and blue components. The

lenses (4) and (6) collect the light from the film and apply it to the blue Avalanche Photo Diode (APD) sensor (7) via the blue separating dichroic mirror (5). The mirror (5) transmits blue light but reflects red and green to the red separating dichroic mirror (8), which reflects the red light through lens (9) to the red APD sensor (10). The remaining green light passes through the mirror (8) and lens (11) to the green APD sensor (12). The three electrical colour signals are then passed through electronic processing circuits, converted into a television signal format and provided as output signals which are typically then recorded on video tape equipment. Alternatively the signals may be converted to video data format and stored in data recording equipment.

It is realised that it would be beneficial to collect more of the light that is scattered by scratches on the surface of, or other deformities in or on, the film. Such scratches cause scattering of the light, which may then be lost from the optical system and cause a reduction in the signal received by the photo sensors, if this light could be effectively collected then the visibility of the scratches would be much reduced. Figure (1) shows the path of the imaged rays passing through the film, and also shows a ray typical of that diffused by a film scratch, it can be seen that this latter ray misses the collecting lenses (6,9,11).

International Patent WO 83/02869 A1 and US patent US 4481414 describe various methods of improving the collection of such scattered light by imaging and or by reflective means. UK patent GB 1409153 suggests a scheme of using additional photo sensors to collect some of this scattered light to enable the substitution of a suitable alternative signal. UK patent application GB 2323495A also discloses improved collection of the scattered light by imaging and reflective means and the use of additional sensors to collect the scattered light and add this in suitable proportion to the main signal.

It is also understood that there is a limit to the amount of this scattered light that can be collected in a practical optical system. This limit is effected by the LaGrange optical invariant that can be referenced at page 2-8 of the "Handbook of Optics" published by the McGraw-Hill Book Company ISBN 0-07-047710-8. In the C-Reality telecine described above the optical invariant infers that the product of the maximum scanned film dimension and the numerical aperture of the rays passing through the film will, in a theoretically perfect optical system, be equal to the product of the maximum active sensor dimension and the numerical aperture of the rays arriving at the sensor. The dimensions of the film is a fixed requirement and that of the sensor is chosen to give best signal performance, whilst the numerical aperture of the rays arriving at the sensor are limited by the sensor characteristics. The maximum numerical aperture that can be collected is therefore limited by these parameters. Light diffracted by a film scratch will normally include a significant proportion outside of this angle that can not be collected. Any attempt to increase the angle of diffracted light collected will result in a loss of imaged light collected or a loss of light from the extremes of the image; neither effect can be tolerated in high performance equipment.

A known solution is to use a larger sensor, however in the example of the C-Reality telecine the sensor is for reasons of best performance chosen to be an avalanche photo diode of 10mm diameter. It is also known that the effective numerical aperture of the photo sensor can, in some instances, be increased by the use of a high refractive index substance fitted between the active surface of the photo sensor and the optical system. A further known method of improving the diffuse ray collection is to use an integrating sphere or cylinder. This method will collect

substantially all angles of light rays from the film, but suffers the disadvantage of being very inefficient so would not collect enough of the imaged light.

The method of this invention is shown in figure (2) and combines a modified form of integrating sphere (15) with a conventional imaging path. An important part of the method is that the conventional imaging path is retained so that all imaged rays arrive at the sensor and no signal degradation is suffered. In order to accommodate the additional integrating sphere an optical relay system (13) and (14) is inserted in the light collection path, this relay system routes the imaged rays directly through the integrating sphere. The diameter of the integrating sphere exit port is positioned at a pupil image and is chosen so that it just passes all of the imaged rays. Some of the diffracted rays from a film scratch will pass through the imaged path in the normal way but others, which would otherwise have been lost, strike the walls of the integrating sphere, and are diffused and bounced around the sphere until they find an exit port. The scratch APD sensor (16) collects a portion of these rays and provides a signal representative of the rays diffracted by film scratches etc.

In a first embodiment of the invention the scratch APD sensor consists of three individual sensors each including a colour filter to match the colour response to that of the red green and blue channel. The signals from the red green and blue scratch sensors are adjusted in level and added respectively to the signals from the red green and blue sensors. This process replaces the signal that has been diffracted by a film scratch, and so reduces the visibility of the scratch in the image. The novel part of this embodiment is the method of using the integrating sphere to provide the three accurate scratch signals without detriment to the main imaged signal collection.

In a second embodiment of the invention it is recognised that the inefficiency of the integrating sphere may not provide a suitably large scratch signal for use in high quality film scanning. The signal collected by the sensors is limited by the radiant power from the cathode ray tube, the density of the film, the efficiency of the collecting system, and the efficiency of the sensors. The signal collected is further limited by the width of the colour spectrum passed to the sensor. In the case of the blue channel for example the energy collected is around 1/20 of the broadband energy available and this is further reduced to about 1/200 by the density of the orange coloured negative film mask. This embodiment therefore uses a single sensor with no colour filtering to give a substantial increase in the collected signal level that compensates for the inefficiency of the integrating sphere. The improved scratch signal so produced is then converted into a scratch flag that indicates the presence of a significant scratch on the film. The scratch flag is used to activate electronic substitution circuitry that replaces the scratched part of the image with data from an adjacent part of the image.

This technique of substituting damaged image data with alternative data from other parts of the picture is well known, and is used for example in video tape recorder "drop out compensation" as well as film damage compensation. As an example the paper "scratch and dirt concealment within a ccd based telecine" (Mead and Childs) from the proceedings of the International Broadcasting Convention 1984, describes a system using detection of infra red rays passing through the film to provide a scratch flag signal that activates a concealment algorithm where the picture information to left and right of the damaged location is blended to replace the damaged area.

The novel part of this first embodiment of the invention is the method of using the integrating sphere to provide an accurate scratch flag signal without detriment to the main imaged signal collection.

A third and preferred embodiment of the invention uses the technique of the second embodiment to improve the scratch signal quality but adds this scratch signal to the main colour channels in similar fashion to the first embodiment. This technique of adding the scratch signal is preferred because it is less likely to produce incorrect results in the presence of detailed and moving pictures. Additionally the scratch flag signal method can only operate successfully with infrequent damage such as film scratches, and cannot provide compensation for film grain. Adding the scratch signal can replace light diffracted by the grains of film and thereby reduce the visible effect of the film grain.

The scratch signal has passed through the colour film yet has a broadband colour response, therefore it will not be in true proportion to the amount of light diffracted away from any one of the main colour channels. However knowledge of the film dye densities, together with the colour response of the four channels (red, green, blue, and scratch), enables the true proportions to be calculated for each channel. The main signals contain the necessary information about the film dye densities, and the colour response of the various channels is known and fixed, so appropriate correction signals can be calculated as follows.

Considering the red channel, most of the light rays diffracted by a scratch on the film will fail to reach the red sensor, so the correction should consist of a signal representing those missing rays. The detected scratch signal will contain a contribution from the band of colours that would have been received by the red

channel, together with a contribution of different proportions from the band of colours that would have been received by the other two channels. To compensate for this mixture of signals the following formula should be applied to the signals.

Red correction = Scratch * k * Red / (a * Red + b * Green + c * Blue)

Where Red correction is the signal to be added to the red signal in order to compensate for scratches etc., Scratch is the detected scratch signal from the detector in the integrating sphere, k is a constant preferably adjustable by the operator to give optimum concealment of scratches, Red, Green, Blue, are the detected colour signals, and a, b, c, are constants representing the proportion of signal collected by the three colour channels with respect to the scratch signal. The value of k is determined by the relative channel gains and the collection characteristics of the integrating sphere, and is most easily determined by empirical adjustment. The values of a, b, c, can be calculated from the relative energy collected by each of the four channels, and should take into account the spectral response of the cathode ray tube, the sensors, the colour separation components, and the film dyes at minimum density. Typical values for operation with colour negative film stock might be a = 0.035, b = 0.1, c = 0.005.

The formula shown above applies to the red channel correction but equivalent formulae would be used for correction of the green and blue channels. It is clear that various equivalent forms of the formulae could alternatively be used, in particular it is convenient to adapt the formulae for efficient use with existing equipment. Figure 3 shows a schematic arrangement of known shading correction circuitry such as is used in the applicant's C-Reality telecine, this circuitry compensates for non uniformity of the optical transmission, sensor sensitivity and cathode ray tube radiant output.. Each colour channel has an equivalent reference sensor, with the same colour response,

aimed directly at the cathode ray tube; this detects signal variations from the cathode ray tube. The first part of the shading correction circuitry divides the main colour signal by this reference signal to remove the cathode ray tube variations. In figure three the main and reference signals for each colour are individually applied to a look up table that gives the logarithm of these signals, then the log reference signal is subtracted from the log main signal in an adder circuit. This process when followed by an antilogarithm stage is equivalent to dividing the main signal by the reference signal. The antilogarithm stage is implemented in following circuitry to allow further logarithmic processing of the signal. The first stage correction of figure 3 is followed by a further adding stage that subtracts a mapped correction waveform corresponding to the optical shading and similar errors. Once again this is equivalent to a division of the signals.

Figure 4 is a schematic representation of one possible arrangement of the invention. The signals generally flow from left to right, the first stages of logarithm, two adders and shading map are as described in figure 3 with the addition of an extra channel for the new scratch signal. The signals then split into two paths, one path has an appropriate constant (a, b, c, or k) added by the adding circuitry and is then passed through a look up table that gives the antilogarithm of the input. The three colour signals are then added together in further adding circuits then applied to a look up table that gives the reciprocal of the input. The scratch signal from the antilogarithm look up table is then multiplied by this reciprocal signal in a multiplier circuit and has a value of unity added to it in an adder circuit before being applied to a look up table that gives the logarithm of the input. This modified scratch signal is then added to each of the colour signals from the shading map adder to produce the corrected colour signals red, green, and blue.

Analysis of figure 4 shows that the following formulae are being applied to the signals.

ln Red + ln (1.0 + e^(ln k + ln Scratch) /

(e^(ln a + ln Red) + e^(ln b + ln Green) + e^(ln c + ln Blue)))

After applying the following antilogarithm stage this result can be simplified into.

Red* (1+k*Scratch / a*Red + b*Green + c*blue) This is simply another form of the previous equation Red + Scratch*Red*k / (a*Red + b*Green + c*Blue).

For best operation of the scratch signal it is preferable that this signal also undergoes shading and reference correction, the shading correction can be done as normal but it is necessary to provide some form of reference signal for the scratch channel. Since the scratch channel has a broadband colour response, one method would be to use an additional reference sensor with an equivalent broadband response. An alternative arrangement is shown in figure 5 where the multiplying and adding stages apply proportions d, e and f respectively of the red, green and blue reference signals are summed to give a scratch reference signal. The proportions d, e and f are chosen to match the relative energies of the three colour signals extracted from the broadband response, and are typically around d = 0.125, e = 0.75, f = 0.125.

The novel part of this third embodiment is the method of using the integrating sphere to provide the accurate scratch signal without detriment to the main imaged signal collection, together with the matrixing of the scratch and colour signals to produce an accurate correction signal for each colour.

The above mentioned signal processing could equally be performed by a software algorithm in a computer system, this method may be preferred for slower data rates.

In figure 2 the collecting lenses are shown symbolically as normal spherical lenses, any of these lenses could consist of a group of lenses, or of lenses of a different type such as aspheric lenses. In particular it is advantageous to place the film close to the sphere entrance port and to minimise the area of this input port. These requirements are better achieved by the use of one or more Fresnel, lenticular, or holographic lenses in figure 2 location 13. The advantage of these lenses is the ability to provide the required power in a thin lens.

Where specific reference is made in the above description to flying spot telecine or film scanners using a cathode ray tube, the same principles would apply to other forms of telecine or film scanner using a scanning light source. In particular a telecine using a scanned laser light source would particularly benefit since the light source is collimated and therefore a narrow aperture collection system could be used. The use of such narrow band collection would cause film scratches and the like to be much more visible, so the benefits of this invention would be even greater.